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transported, so appropriate to the Carthaginian navigators who monopolized the *carrying trade* of the ancient world. This quality is symbolized by the horse, the type of transportation all over the world, and chosen by all poets as the emblem of the sea, from Homer in the Fourteenth Book of the Iliad to Byron in the finale to Childe Harold.

This emendation was suggested to me many years ago by my late revered father.

Six hundred and thirty-ninth Meeting.

January 9, 1872. — MONTHLY MEETING.

The CORRESPONDING SECRETARY in the chair.

Professor J. P. Cooke read the following statement by the Rumford Committee of the grounds on which the Rumford Medal was awarded to Joseph Harrison, Jr., of Philadelphia, by vote of the Academy passed May 30, 1871. This statement was adopted by the Committee at a full meeting held December 23, 1871.

An award of the Rumford Medal was made at the annual meeting of the Academy, May 30, 1871, in the following terms: — "Voted, that the Rumford Medal be awarded to Joseph Harrison, Jr., of Philadelphia, for his mode of constructing steam-boilers, by which great safety has been secured."

The "Harrison Boiler" consists of a number of hollow cast-iron spheres, about eight inches in external diameter, and three eighths of an inch thick. These spheres are cast in groups of two or four, the spheres of each group being arranged in straight lines, and connected with each other by curved necks about three and one quarter inches in diameter. Moreover, each sphere has two half-necks, which make openings at right angles to the necks previously mentioned. The open necks are rabbeted, so that any number of the groups of spheres (units, as they are called) may be united to each other, and the system thus built up is held together by wrought-iron tie-bolts, which pass through each line of spheres in the direction of the half or jointed necks, connecting at each end with caps that close the external orifices of the end spheres on each line. The castings are made with such uniformity, and the necks turned so as to fit each other with such accuracy, that when the rabbeted edges are adjusted and drawn together by the screw and nut at the end of each bolt, a perfectly steam and water tight joint is secured, without the intervention of cement or packing. A system of spheres thus united, six wide and twelve or thirteen long, forms what is called a section ; and a boiler consists of several of these sections, all discharging steam into the same pipe. In setting the boiler the sections are placed on edge, side by side, so that the lines of bolts make an angle of about forty degrees with the furnace grate.

The security of the Harrison boiler depends on the following features in its mode of construction. In the first place, the spherical form, adopted for the units of the boiler, greatly economizes the tensile strength of the iron, and it has been estimated that, with a metal having a tensile strength of three and one half tons to the square inch, the bursting strength of the units would be nearly three fourths of a ton per square inch. The strength of a boiler consisting of such units will, of course, be no greater than that of the weakest sphere of the structure; but as all the sections are tested at the manufactory by hydrostatic pressure, as high as three hundred pounds to the square inch, a defective unit is discovered before the boiler is delivered to purchasers.

It is not maintained, however, that the units of the Harrison boiler cannot be burst under excessive pressure; for, as experience has shown, it is impossible to make a vessel, at least one of any practical value as a steam-generator, which cannot be burst. It is merely a question how high a temperature it can stand before yielding. But the evidence before the Rumford Committee has sustained the opinion that, in case of such an accident to the Harrison boiler, a violent destructive explosion is almost impossible ; and this brings us to the consideration of the second feature on which the security of this boiler depends.

In an ordinary plate-iron boiler the yielding at any point almost inevitably involves the rending and complete destruction of the whole structure. A tear started at a defective rivet, or on a line of corrosion, will instantly lay open the whole vessel, when the expanding steam scatters the contents in all directions, and hurls the fragments with a force which no ordinary constructions of buildings or ships can withstand. The recent experiments of Mr. Stevens, of Hoboken, as described in a report to the Secretary of the Navy by three of the chief engineers in the naval service, show very conclusively that this tearing apart of the boiler-plates under pressure is the simple cause of the destructive explosions of plate-iron boilers, and, to use the words of the report, "that in accounting for either the fact of an explosion, or for its destructive effects, there is no necessity for hypothesis of low water, enormous pressures, instantaneous generation of immense quantities of steam, superheated steam, the formation of hypothetical gases, the development of electricity, &c., &c. The most frightful catastrophe can be produced by simply gradually accumulating the pressure of the saturated steam to a strain, at which the strength of the boiler yields, nor need that pressure be much above what is ordinarily employed with boilers of this type." In one experiment the boiler exploded with most destructive violence in less than a quarter of an hour after the pressure had passed the inspector's limit.

Such a sudden tearing open of the whole vessel has never taken place, and does not seem to be possible, with the Harrison boiler. Under an excessive pressure the weakest units in the system may yield, and injury may be caused by the sudden discharge of water, or of steam; but the injury to the boiler must be, to a great extent, local, probably extending only to the breaking of a single unit, and involving, at the most, a rapid but still regulated emptying of its contents. The parts being wholly independent, there is no tendency in a rupture to extend from one unit to its neighbor's; and moreover, as a general rule, long before the bursting-point is reached, a third feature of the boiler comes into play, which, perhaps, more than either of the other two, protects it from destructive explosions. The units of the boiler not being cemented together, the least yielding of the tie-bolts opens every joint and makes each of them a safety-valve. That this is the normal action of the boiler under excessive pressure has been abundantly established, not only by the experiments made by Mr. Harrison before a committee of the Franklin Institute, but also by the experience of a member of our own committee.

The Rumford Committee were satisfied, by the evidence herein stated, that the Harrison boiler is not liable to those violent destructive explosions referred to above, and to which the ordinary plate-iron boilers, however carefully or strongly made, must be always more or less exposed. Considering further the economical advantages to be gained from high-pressure steam, and the paramount importance of such security as Mr. Harrison has attained in the use of this powerful agent, they felt themselves justified in making the recommendation, on which the Academy acted, in awarding to him the Rumford medal. It must be noticed, however, that the award has been made for a "mode of constructing steam-boilers, by which *great safety is secured*," and that the safety of the boiler is the only point on which the committee based their recommendation. They did not feel themselves called upon to weigh carefully the relative merits of the Harrison boiler when compared in other respects with the many forms of steam-boilers now in use. They considered that its already extended and rapidly increasing use was sufficient evidence that the Harrison boiler was an efficient and economical steam-generator. More than this they did not require to be proved; for whatever might be the defects of the boiler, — and some doubtless there are, — the committee considered that Mr. Harrison had made an important advance in the application of steam by demonstrating experimentally the principles on which a safe steam-boiler can be made, and working them out to a practical result. These principles being established, we may hope that any defects in the present construction may be hereafter remedied.

It remains only to consider how far the principles or features of construction to which we have referred are original with Mr. Harrison. At least twenty-five years ago Dr. Ernst Alban, a distinguished German engineer, clearly recognizing the impossibility of securing safety in a steam-boiler by strength of materials alone, advanced the important opinion that the only sure method of avoiding danger is "so to construct the boiler that its explosions may not be dangerous"; and in a valuable work originally published in Germany, but of which an English translation, published in 1843, was alone before the committee, a mode of constructing steam-boilers is described in which this principle is skilfully applied. Mr. Harrison has adopted the principle of Dr. Alban, and, in a pamphlet on the steam-boiler, published at Philadelphia in 1867, he prints the opinion of Alban, quoted above, at the head of his essay; but his method of embodying this principle is as dissimilar as possible. Moreover, he has carried out the principle more fully than Alban himself. The German boiler, like the American, is made in sections, so that the bursting of one would bring no destructive consequences from the general body of the boiler; but it is merely a modification of the well-known tubular boiler, and does not combine the advantages which Harrison obtains from the spherical form of his units, and the mode by which they are bolted together without rivets or cement.

But the merit of Mr. Harrison and his claim to the Rumford medal consists fully as much in the skill with which he has overcome the difficulties in the details of the construction of his boiler as in the ingenuity of the original design. The boiler is not an ideal conception, but an accomplished result, of which the industry of the country is enjoying the benefit. By Mr. Harrison's labors, high-pressure steam has been brought more under control, and human life has been rendered more secure. The Rumford Committee believe not only that in awarding the Rumford medal to Mr. Harrison the Academy are faithfully carrying out the expressed wishes of their benefactor, but also, that Mr. Harrison's invention is one which Count Rumford would have especially delighted to honor.

Professor Joseph Lovering then received the medal from the Chairman of the Rumford Committee, and presented it to Mr. John A. Coleman, who was delegated by Mr. Harrison to act as his substitute on the occasion, and presented it with these remarks: —

This full and authoritative statement of the Rumford Committee, which its Chairman has now presented, — covering as it does the whole ground, and clearly indicating the substantial reasons for the award of the Rumford Medal to Mr. Harrison, — renders further remarks from the Chair superfluous.

Acting by the request of your President, Dr. Asa Gray, who would not be able to speak this evening, even if it were safe for him to be present, I have only, in behalf of the Academy, to receive this medal from the Committee, who have so well done their part in producing it, and in justifying its bestowal, and to deliver it into the hands of the recipient's representative, since Mr. Harrison himself is unable to be with us upon this occasion.

As the founder of this premium was especially solicitous that it should stimulate those discoveries or inventions which tend to increase the comforts and conveniences of life, we may well conclude that he would regard with highest favor those that conduce to the preservation of life itself. The invention of Mr. Harrison is of this kind, is one which, it is thought, may render certain applications of heat, themselves of immeasurable importance, measurably secure, may render the steam-boiler for general mechanical purposes as safe as any other mode of generating power.

And now, Mr. Coleman, in the Academy's name, I deliver this gold medal, and its silver duplicate, to you, to be carefully transmitted by you to Mr. Joseph Harrison, Jr., whose name is inscribed upon them. The Secretaries will add an engrossed and attested copy of the proceedings of this meeting relative to the subject. Be pleased, my dear sir, to convey them to the hands of the gentleman whose invention the Academy desires to honor and to crown; and take with them to him the felicitations and the hearty good wishes of the Fellows of the American Academy of Arts and Sciences here assembled to administer Count Rumford's trust.

After Mr. Coleman had received the medals, he read the following response, directed to the President and Members of the American Academy of Arts and Sciences.

MR. PRESIDENT AND GENTLEMEN: —

In receiving the Rumford Medals, which have been awarded to me in so flattering a manner by the American Academy of Arts and Sciences, I fear that I cannot express in suitable terms my appreciation of this distinguished honor. I can, therefore, only say, that I do esteem this compliment very highly indeed, and I shall ever cherish these tokens with the greatest pride. To my mind, there is nothing within the limits of science at the present time that is of more importance than the "application of heat" to the safe generation of steam, and to have won a recognized distinction in such a field, and to have been deemed worthy of the reward that your honorable Society has bestowed upon me, fully repays me for many years of anxious, and often of discouraging, effort. In what I have done I claim but little merit beyond having called attention, for the last twelve years, to the great importance of the question, and in having in some degree demonstrated the fact that a Steam Generator can be made secure from destructive explosion. I think that this idea has now taken such a firm hold upon the public mind, both in this country and in Europe, that it may be fairly inferred that in the future the use of steam under pressure, no matter what form the apparatus may eventually assume, will not be attended with the disastrous results that are recorded in the past. In expressing my regret at being unable to attend your meeting on January 9th, so as to receive the medals in person, I most sincerely thank you, Mr. President and Members of the American Academy of Arts and Sciences, for this very high mark of your approbation.

JOSEPH HARRISON, JR.

Philadelphia, Jan. 6, 1872.

Professor E. C. Pickering exhibited a new form of dividing engine in which the scale to be engraved is moved forward equal amounts at each stroke, the distance being regulated by a pin moving between a plate of brass and the end of a screw. In this instrument, as there are no joints, this source of inaccuracy is avoided, and it is also free from the usual errors of a micrometer screw. The model shown, although made of pine-wood, gave results approaching in accuracy those of the best metal dividing engines.

Professor N. S. Shaler made a communication on the connection between the development of the life and the physical conditions of the several continents.

It has been shown that the several continents vary in the extent to which their shore line is irregular. If we arrange the several continents according to the amount of shore line compared with the internal area, we get a series in which they stand in the following order: Europe, North America, South America, Australia, Asia, Africa; but if we represent the continents in such a fashion that all have the same area, retaining for each the general outline which it now has, then we obtain a series in which Australia has the least shore in proportion to area, South America next, Africa and Asia next and approximately equal, North America next, and Europe the highest in the series, having several times as much shore line as Australia and much more than North America. It will be evident, on consideration, that this analysis enables us roughly to compare the conditions of surface on the several land masses. Those which have the largest amount of shore line in relation to area are those which have the most diversified surfaces, and conversely. With this series let us compare another series derived from the development of life on these continents. If we take these continents and tabulate their organic life, in so far as is necessary to determine the number of ancient types surviving on each, we may construct another series. It is true that this will be only approximative, but it will indicate the relative zoölogical inferiority of any continent, so far as we can infer that from the survival there of types of organic life which have disappeared from the others. This second series will correspond with the first, the continents being inferior as a whole in their organic development in proportion to the relative shortness of their shore lines: or, in other words, to the want of variety of their surfaces.

To see the connection between the development of life on the several continents and the variety of their outlines, it will be necessary to consider, from the point of view of Mr. Darwin, the difference between the conditions in which life is developed on two surfaces of equal area but differing very widely as regards the irregularity of the surfaces. In the first place, the irregularity of any extended land surface is in a general way a good measure of the number of important geological accidents to which the region has been subjected. There can be no question that Europe, the most varied of the continents in external surface, has many more distinct mountain systems than North America, the next in our series. Each of these "systems" is the mark of a wide-spread change of physical conditions which has brought important disturbances into the relations of the life by such accidents existing on sea and land. Many species would be extinguished, and, of those which survived, many would have to adapt themselves to new conditions, and so change and advance are made possible. Again, there is a direct and constant influence exercised by diversity of surface. The number of specific forms, and the consequent energy of the struggle for existence on any continent is, other things being equal, dependent upon the variety of conditions it offers to life. Compare two equal areas of, say, one hundred miles in extent, the one a level plain, the other thrown into a mountain mass, which extends from the tropics at the base to the frigid zone at its summit of perpetual snow. On the one you may find essentially the same organic forms throughout, and the competition is at the minimum; on the other, every mile of ascent brings you in contact with new forms, all the conditions of land life are crowded together, and their varied creatures put into such immediate contact that the struggle must be very much intensified. The seeds of plants belonging on the different zones, the insects which depend upon them, the many creatures dependent on the plant or insect life, are often swept by the streams or the winds, or forced by want of food into new conditions of life; cross-fertilization of plants and animals is far more likely to take place in these metropolitan centres of life than where the boundaries of species are made by barriers more insuperable than a mile of mountain slope.

Professor John Trowbridge presented the following remarks on Animal Electricity: —

The investigations of Du Bois Reymond, Matteuci, and others have left, apparently, no doubt of the existence of electrical currents in nerve and muscle.

Physiologists have been led from considering the anomalous contractions of the galvanoscopic frog to conclude that there exist in the muscles and nerves of man, of fishes, and in the various organs of the lower forms of life, currents which have determinate directions. The earlier investigators tested for the presence of these currents by touching the organs or parts to be examined with the bare terminals of the galvanometer; indeed, this method of investigation is still pursued by certain physiologists.

The evidence of the existence of animal currents produced by touching the muscles with the bare terminals of a galvanometer or an electrometer is entirely insufficient to prove that electrical currents circulate in the muscular or nerve tissues. One is baffled at every step by the dissimilar composition of the terminals; by the changes which they undergo from the action of the air upon the fluids adhering to the surface of the platinum; and by the influence of heat.

It is true that by experimenting with the bare terminals one can state a difference in the chemical nature of the different tissues of the muscle or nerve; we cannot, however, conclude that electrical currents exist in a determinate direction between such tissues; indeed, in many cases the galvanic action is evoked by the action of the metallic plates of the terminals. This unequal composition of the two electrodes can be overcome, as Matteuci has shown, by using amalgamated zinc terminals placed in a saturated solution of sulphate of zinc.

Du Bois Reymond, by using connecting pads of filtering-paper, saturated with the salt of the connecting liquid, with clay or bladder guards to prevent the muscle from coming in contact with the sulphate of zinc, was enabled to prosecute his investigations without fear of errors arising from the changes in the metallic terminals. At first sight it appears as if this method of experimenting left nothing to be desired. The sulphate of zinc is a good conductor; the zinc plates produce only a slight action when immersed in the sulphate of zinc, and this action can be readily compensated by a magnet or by a compensating current. The muscle can be touched at any part by the pads of filtering-paper or by the clay talons which Du Bois Reymond afterward used, without danger of injuring the animal tissue.

It occurred to me, however, from certain experiments upon the electromotive force arising from two liquids of a dissimilar chemical nature separated by a porous partition or by a membrane, that a serious error might arise in using even the pads or cushions of Du Bois Reymond, arising from the action of the vital fluids of the muscle upon the sulphate of zinc through the clay or membranous guards.

In experimenting upon the action through membranes I used an oblong vessel divided into four partitions by means of pieces of pig's bladder soaked in the white of an egg. In the outer compartments were placed the zinc electrodes in the solution of sulphate of zinc, and in the middle compartments the liquids to be examined. Owing to the unequal action of the sulphate of zinc through the partitions, even when the inner compartments were filled with one and the same liquid, an energetic swing of the needle of the galvanometer resulted.

The experiments with this apparatus made it evident that a very slight difference in the partitions enclosing a fluid and separating it from a surrounding homogeneous connecting liquid, together with the resulting endosmotic action, is sufficient to produce an electrical current.

I next made use of the apparatus of Du Bois Reymond, which I have already described. Having connected the two cushions by the connecting pad, and having laid a piece of bladder treated with the white of an egg over the connection thus formed, I made use of a series of tubes filled with the following liquids:

Distilled water.
Undistilled water.
Blood.
Solution of salt.
Solutions of iron.

Applying these tubes, having covered their openings with bladder, upon the connecting guard, I found that each liquid gave rise to a current which varied in direction with the nature of the fluid. These currents were evidently due to the action of the fluid in the artificial muscles upon the sulphate of zinc in the connecting guard, for distilled water gave no appreciable current, and the mere contact of the bladder of the tube upon the bladder of the guard was insufficient to produce an action. In order to be certain of this, I next made use of a vessel shaped like a U tube, with an opening at the bend, and having covered the ends of the tube with a membrane, I injected into the two limbs the liquids with which I experimented. When the vessel was filled with a homogeneous fluid, a deflection of the needle of the galvanometer was produced. Upon the reversal of the points of contact of the vessel with the guard, the direction of the needle was also reversed. That the current did not arise from the mere contact of the vessel with the guard was shown by applying its limbs unfilled with liquid; in this case no appreciable deflection of the needle resulted. That it arose from the action of two fluids separated by a membrane, one of them being the connecting liquid in which the cushions of the galvanometer were soaked, was evident by changing the composition of the liquid in the limbs of the U tube.

Desiring to test the direction of the current in order to see if it passed through the U tube, or merely, having arisen at the extremities of the tube, passed through the galvanometer back to its origin, I used an apparatus by means of which I was enabled to contract the section of one of the limbs of the U tube. This in all cases reduced the deflection of the needle in a marked manner, a complete constriction of the limb bringing the needle to rest.

My experiments led me to believe, that when the cushions of the galvanometer are connected by a membranous sac containing fluid, or animal tissue saturated with fluid, an endosmotic action takes place accompanied by a galvanic action; and that this galvanic action is determined by the difference of endosmotic action at various points of the enclosing membrane.

When, therefore, a muscle is laid upon the cushions with its transverse section upon one pad, and its longitudinal section upon the other, this difference of endosmotic action obtains, and a galvanic current results.

If the muscular and nerve currents exist, this endosmotic action must greatly modify their direction and strength. If they do not exist, the endosmotic action, or the electrical action of two fluids separated by a clay or membranous partition, is sufficient to produce currents which may be mistaken for the muscular currents, properly so called.

In order to study these phenomena, the same precautions must be taken as are advised by Du Bois Reymond (Untersuchungen über Thierische Electricität. Bd. I.: Beschreibung, etc., 1863, p. 95, *et seq.*) in the study of muscular currents. It must be considered that the fluids in the fresh muscle in their natural position are more energetic in their chemical nature than when they are taken from the muscle or nerve and experimented upon.

I used in my experiments one of Sir William Thompson's Reflecting Galvanometers, and also his new Quadrant Electrometer.